Telemicrosurgery in Brachial Plexus: the Feasibility of Robot-Assisted Microsurgery

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Telemicrosurgery applications have expanded quickly since the 1990s. The development of robotics has allowed a glimpse into new perspectives in nerve microsurgery. Minimally invasive surgery has quickly become the first therapeutic option in many operative indications, reducing postoperative complications and increasing patient comfort. Surgical robotics already proved useful, leading to numerous enhancements of the technique. We will introduce you how to make telemicrosurgery of the brachial plexus surgery with da Vinci robot in this review.

In Oberlin technique, our results demonstrate the feasibility of the robot-assisted surgery. The absence of sensory feedback was not a problem. The development of specific retractors should improve the mini-invasive technique.

In brachial plexus surgery, mini-invasive robot-assisted brachial plexus surgery has the double advantage of better cosmesis and improved functional outcome by decreased scarring. It was difficult to confirm with absolute certainty without electrical stimulation that the nerve identified and biopsied was the superior trunk of the brachial plexus. We had no other difficulties with this procedure. The workspace was perfectly maintained by low-pressure insufflations of CO2.

In telemicrosurgery, we think that there are many requiring ingenuity. More animal research and clinical study will be needed to develop the field of telemicrosurgery. We believe that Juntendo University will be able to do it and have to do it!!

Key words: telemicrosurgery, microsurgery, da Vinci robot

Introduction

Telemicrosurgery applications have expanded quickly since the 1990s and will soon compete with conventional microsurgery.

The development of robotics has allowed a glimpse into new perspectives in nerve microsurgery. Robots have properties adapted to microsurgery: three-dimensional vision magnified up to 40X, movements of the surgeon magnified up to 10X, elimination of physiologic tremors, and comfortable work in positions reputed to be antiergonomic.

Minimally invasive surgery has quickly become the first therapeutic option in many operative indications, reducing postoperative complications and increasing patient comfort. Surgical robotics already proved useful, leading to numerous enhancements of the technique.

Several interventions remain almost inaccessible to endoscopic surgery, such as brachial plexus injuries, affecting mostly young patients and leading to severe functional disability. Open techniques are still the gold standard of brachial plexus surgery. Development of minimally invasive and robot-assisted surgical approaches has the potential to greatly improve the surgical outcome.

We will introduce you how to make telemicrosurgery with da Vinci robot in this review.
The Oberlin procedure for restoration of elbow flexion with the da Vinci robot: four cases

Our series included four patients presenting with elbow flexion paralysis. They underwent surgery at an average of 8 months after injury performed by the same surgeon under general anesthesia in supine position.

A surgical robot model, da Vinci S® (Intuitive surgicalTM, Sunnyvale, CA), was installed. The movements of the instruments were multiplied by 5. The camera allowed three-dimensional vision and progressive magnification up to 25X.

We have adapted the Oberlin technique7 to robotics in three stages: installation of the robot, approaches, and nerve transfer. Three patients were operated on using the open technique (technique 1), and the mini-invasive technique (technique 2) was used for the last patient. In technique 1, the upper limb was positioned in 90 degrees’ shoulder abduction and elbow extension on an arm table. The robot was placed on either side of the upper limb, the mobile trolley outside the arm, and the instruments inside the arm (Figure-1A). In technique 2, the upper limb was placed at 90 degrees’ abduction, 90 degrees’ external rotation of the shoulder, and 90 degrees’ elbow flexion on an arm table. The robot was placed on either side of the trunk, with the mobile trolley on the contralateral side and the instruments on the operative side (Figure-1B).

In technique 1, the origin of the branch of the musculocutaneous nerve to the biceps and the ulnar nerve were identified at the same level. In technique 2, we prepared four skin approaches of 8 mm each at the medial aspect of the arm, separated from each other by 3 cm, and 9 cm away from the origin of the branch to the biceps. Three arms holding the instruments were introduced through the two medial and far lateral incisions, and the video camera was introduced through the remaining incision. A space was created by dissection using bipolar scissors and forceps and maintained using carbon dioxide insufflation at 4 mmHg. The nerve transfer technique was identical for both techniques and was performed using the telemicrosurgery instruments. The nerve branch to the biceps was isolated over approximately 2 cm using Black Diamond forceps® (Synergetics, Inc., O’Fallon, Mo.) and cut with a pair of Pott’s microscissors®. The distal part of this branch was directed medially toward the ulnar nerve, and the ulnar nerve epineurium was incised using the Pott’s microscissors®. A motor fascicle to the extrinsic muscles of the hand was identified by electrostimulation (Figure-2A) and separated distally from the rest of the ulnar nerve over 2 cm (Figure-2B). This fascicle was then directed laterally and sutured to the nerve to biceps using two 10-0 stitches (Figure-2C). Some drops of biological glue (Tissucol; Baxter, Deerfield, Ill.) were applied to the suture line (Figure-2D). Result were evaluated using force of elbow flexion.

Figure-1 Patient positioning and preparation
A. In open technique 1, the upper limb is placed at 90 degrees’ shoulder abduction and elbow extension on an arm table. The monitor shows the extremity of the ulnar motor fascicle and the branch to biceps ready for suture.
B. In mini-invasive technique 2, the left upper limb is placed at 90 degrees’ abduction and 90 degrees’ external rotation of the shoulder, and 90 degrees’ elbow flexion on an arm table. The video camera arm was equipped with a carbon dioxide insufflation system to enlarge the operative field.
measurements.
Clinically, at 12 months’ mean follow-up, all patients had recovered useful elbow flexion. No sensory motor deficit in the ulnar nerve territory was found. There was no difficulty with technique 1. In technique 2, the carbon dioxide pressure of insufflation was not enough to keep subcutaneous tissue far enough away from the camera. Vision was blurred. The portals were not airtight and the leaks were greater than what the insufflation system could compensate for to maintain enough pressure. After 30 minutes, the decision was made to convert to the open technique (technique 1). From then on, the procedure was uneventful.

Mini-invasive robot-assisted surgery of the brachial plexus: a case of intraneural perineurioma

A right-handed 12-year-old girl was referred to us by a neuropediatrician for a right upper limb problem.
She presented with a right congenital torticollis (Figure-3A) accompanied by intermittent lateral cervical pain scoring 3/10 on a visual analogue scale. Neurological examination was otherwise normal. Magnetic resonance imaging (MRI) revealed a lesion of the right brachial plexus suggesting an intraneural perineurioma (Figure-3B). The somatosensory potentials showed a definite asymmetry in latency and amplitude between both sides.
A biopsy was requested to confirm the diagnosis and exclude malignancy.
The patient was operated under general anesthesia in a dorsal position. Three subclavicular incisions of 8 mm each were prepared. The operative field was prepared by subcutaneous dissection through the incisions to the cervical region (Figure-4A). Three trocars were placed with the central one for the scope and the peripheral ones for the instruments (Figure-4B). CO2 gas insufflation was connected to the scope trocar at 4 mm Hg pressure. A da Vinci S® robot (Intuitive surgical™, Sunnyvale, CA) was installed at the head of the patient (Figure-4C), so that the instrument arms and the

Figure-2 Views of the operative field
A. The ulnar nerve is isolated on a vascular sling. A motor fascicle is identified by electrostimulation operated by a robot.
B. The donor motor fascicle of the ulnar nerve is cut.
C. The donor motor fascicle of the ulnar nerve (lower portion of figure) is sutured to the motor nerve to the biceps (upper portion of figure) using 10-0 suture manipulated by the robot.
D. Tissue glue is applied to the nerve suture. The needle containing the glue is manipulated by the robot.
Figure 3  Preoperative appearance of intraneural perineurioma of the right brachial plexus
A. Clinical appearance showing cervical deformity.
B. Magnetic resonance imaging showing fusiform enlargement of branches of brachial plexus enhanced after gadolinium injection.

Figure 4  Installation for biopsy of intraneural perineurioma of the right brachial plexus
A. Creation of surgical space. Three subclavicular incisions were made. The surgeon dissected the subcutaneous plane to the cervical region.
B. Trocar insertion; the central one for the scope of the da Vinci® robot (Intuitive Surgical™, Sunnyvale, CA) and insufflation and the other two for the robot instruments.
C. Installation of the da Vinci® robot. The end of the scope was directed toward the cervical region.
D. Progressive dissection up to the branches of the brachial plexus.
camera were inclined toward the posterior cervical region (Figure-4D). Soft tissue dissection was performed using Maryland® forceps up to the upper trunk, which appeared macroscopically normal (Figure-5A). A black Diamond® forceps and Potts scissors were used to take a 3-mm biopsy of a nerve fascicle (Figure-5B and C). The da Vinci® robot and trocars were then removed and the three incisions closed with 3-0 nylon without a drain (Figure-6). Careful mobilization was started on postoperative day 1.

No sensory or motor deficit was observed postoperative. The histological analysis reported abnormal nerve fibers with no signs of malignancy. No further treatment was proposed.

Discussion

In the Oberlin procedure, no technical difficulty was encountered for the open technique; moreover, the telemicrosurgery phase seemed easier than conventional microsurgery. The most important advantages of telemicrosurgery are the disappearance of physiologic tremors and the magnification of movements up to 10X, which ameliorates precision performance. Reasons for failure of the mini-invasive technique include number of incisions, absence of sensory feedback, and failure to maintain a dissection space.

The absence of sensory feedback is often cited as a fault of surgical robots. We had no difficulty with
this, probably because this is not necessary even in conventional microsurgical anastomosis \(^9\).

Contrary to laparoscopic surgery, where there is a natural cavity, the creation of space is necessary in limb surgery. The cause of the failure in technique 2 was attributable to inadequate carbon dioxide insufflation to compensate for the leakage through the incisions. Maximum insufflation pressure in laparoscopic surgery is 15 mmHg\(^{10}\) to avoid complications \(^{11}\). Certain authors propose the use of balloons to create the space \(^{12}\), but the volume needed for this is incompatible with limb nerve surgery, which necessitates dissection of the nerve over several centimeters. Our results demonstrate the feasibility of the robot--assisted Oberlin technique. The absence of sensory feedback was not a problem. The development of specific retractors should improve the mini-invasive technique.

Brachial plexus surgery involves open microsurgical techniques that require extensive incisions of many centimeters extending from the mastoid process to the upper one-third of the arm \(^{13}\). This results in unsightly fibrotic scars and perineural fibrosis, which impairs the quality of functional recovery after nerve repair \(^{14}\). Mini-invasive robot--assisted brachial plexus surgery has the double advantage of better cosmesis and improved functional outcome by decreased scarring.

We used the technique described by Mantovani \(et al\) \(^{15}\) for our case. Apart from difficulties related to identification of anatomic structures, we have been totally satisfied with this technique. It was difficult to confirm with absolute certainty without electrical stimulation that the nerve identified and biopsied was the superior trunk of the brachial plexus. The junction between the external jugular vein and the branching of the thought--to be suprascapular nerve was the sole internal anatomic landmark. We had no other difficulties with this procedure. The workspace was perfectly maintained by low--pressure insufflations of CO\(_2\).

**Conclusion**

We show that the robot--assisted brachial plexus surgery is feasible and we have to try to make mini--invasive robot--assisted brachial plexus surgery in future. In telemicrosurgery, we think that there are many requiring ingenuity. More animal research and clinical study will be needed to develop the field of telemicrosurgery. We believe that Juntendo University will be able to do it and have to do it!!

**References**